Comparison of Techniques for the Measurement of Tissue-Blood Partition Coefficients in Healthy and Infarcted Myocardium

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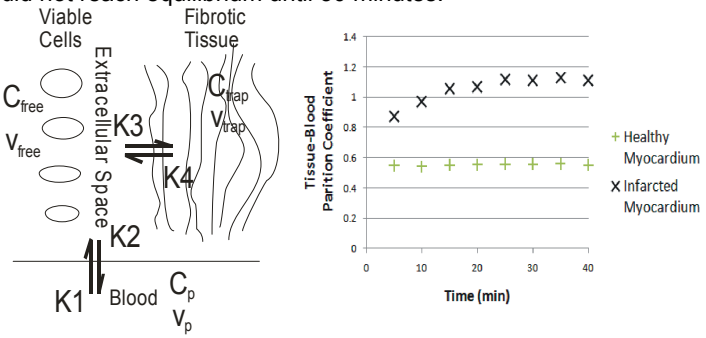
Introduction: Late gadolinium-enhanced myocardial infarct imaging is firmly based on a greater gadolinium (Gd) contrast agent concentration in irreversibly injured myocardial tissue when compared with healthy myocardial tissue. An assumption is made that the contrast agent vascular supply of the tissues is equivalent. The tissue-blood partition coefficient is usually defined as the ratio at equilibrium between the contrast agent concentration in myocardial tissue and its concentration in tissue plasma. The partition coefficient can also be defined as the concentration difference across a well defined membrane (1). A simple ratio suffices in the case of a two-compartment model and has been shown to be larger in fibrotic tissue (2,3), but in the case of a three-compartment model, the distribution across the tissue-blood interface is more complicated. The purpose of this study was to investigate the temporal dynamics of the two-compartment tissue-blood partition coefficient and compare it to estimates using a three-compartment model. The three compartment model can calculate the partition coefficient between blood and the "free" extracellular matrix since it incorporates a third "trapped" fibrotic compartment.

Materials and Methods: Twenty-five individuals (23 men and two women; age mean±std, 61.5±9.9 years) underwent MR imaging at 1.5T. All subjects in this study had a prior SPECT study as part of their routine medical care and the diagnosis of myocardial infarction. The infarct age ascertained from medical history was on average 11.6±10.1 years and ranged from 2 to 31 years. Single slice T1 measurements were performed before contrast administration and after injection of 0.2 mmol/kg of gadodiamide, approximately every two minutes using an inversion recovery CINE balanced steady-state free precession technique. Gd-concentrations of blood, viable, and infarcted myocardium were calculated and interpolated to one minute intervals and averaged across all subjects. The blood Gd-concentration was modeled with a bi-exponential and myocardial tissue Gd-concentration with a three compartment model, including vascular (plasma), free and trapping compartments (Fig 1A). Fractional volumes for the three compartments and transfer constants into and out of the compartments were fitted parameters of the model.

A conventional estimate of the two-compartment tissue-blood partition coefficient was calculated as: lambda1 = (1/T1PostMyo – 1/T1PreMyo)/ (1/T1PostBlood – 1/T1PreBlood) over a forty mintue interval for viable and infarcted myocardium. A formula, K1/(K2+K3), proposed in reference (4) assumes that the contrast agent remains in the trapping compartment and the formula, (K1+K4)/(K2+K3), which takes into account the fact that the contrast agent can move from the trapped fibrotic compartment back to the free compartment were used to calculate additional tissue-blood partition coefficients. Ratios of the transfer constants in and out of the individual compartments which are equivalent to the fractional volumes in each compartment were also calculated and compared ($K1/K2=v_{free}$ and $K3/K4=v_{trap}$).

Results: As displayed in the graph below, the tissue-blood partition coefficient calculated using the ratio method was always greater for infarcted myocardium than viable myocardium. The value was stable for healthy myocardium, but the value for infarcted myocardium did not reach equilibrium until 30 minutes.



Left: Three compartment model with vascular, free and trapping compartments. Right: Although the partition coefficient of infarcted myocardium calculated using the two-compartment ratio methods is greater than that of healthy myocardium, equilibrium of the partition coefficient is not obtained until after 30 minutes.

Table 1	K1/(K2+K3)	(K1+K4)/(K2+K3)	K1/K2	K3/K4	lamda1 (30 min)
Infarcted Myocardium	0.54	0.76	0.59	0.43	1.11
Viable Myocardium	0.47	1.43	0.49	0.04	0.56

Ratios of transfer constants from a three-compartment model provide estimates of the tissue-blood partition coefficient. Little difference is seen unless transfer constants from the trapping fibrotic compartment are used. The largest difference is seen in the ratio of trapping transfer constants (K3/K4).

Conclusions: The measurement of the tissue-blood partition coefficient based on the ratio of T1 relaxation time differences between myocardial tissue and blood is time dependent and different between viable and infarcted myocardial tissue. The measurement of the tissue-blood partition coefficient using a three compartment model yields similar values between infarcted and viable myocardium and T1 relaxation differences are likely due to a third trapping compartment.

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